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Published in:
Preventive Veterinary Medicine

Link to article, DOI:
10.1016/j.prevetmed.2016.01.005

Publication date:
2016

Document Version
Peer reviewed version

Accepted Manuscript

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PII: S0167-5877(16)30002-2
DOI: http://dx.doi.org/doi:10.1016/j.prevetmed.2016.01.005
Reference: PREVET 3953

To appear in: *PREVET*

Received date: 7-4-2015
Revised date: 27-11-2015
Accepted date: 2-1-2016

Please cite this article as: Dórea, Fernanda C., Elbers, Armin R.W., Hendrikx, Pascal, Enoe, Claes, Kirkeby, Carsten, Hoinville, Linda, Lindberg, Ann, Vector-borne disease surveillance in livestock populations: a critical review of literature recommendations and implemented surveillance (BTV-8) in five European countries.Preventive Veterinary Medicine http://dx.doi.org/10.1016/j.prevetmed.2016.01.005

Vector-borne disease surveillance in livestock populations: a critical review of literature recommendations and implemented surveillance (BTV-8) in five European countries

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Highlights:

- Passive surveillance is the most effective early detection strategy for exotic vector-borne diseases
- Detection of vector-borne emerging diseases is very context and area specific, and thus active surveillance designs need to take the available epidemiological, ecological and entomological information into account
- Preparedness is of fundamental importance in determining the timeliness of detection and control against emerging vector-borne diseases
- The degree of voluntary engagement of stakeholders is key on surveillance against vector-borne diseases, highlighting the importance of engaging the public by general awareness and dissemination of results

Abstract

Preparedness against vector-borne threats depends on the existence of a long-term, sustainable surveillance of vector-borne disease and their relevant vectors. This work reviewed the availability of such surveillance systems in five European countries (Denmark, France, The Netherlands, Sweden and United Kingdom, part of the CoVetLab network). A qualitative assessment was then performed focusing on surveillance directed particularly to BTV-8. Information regarding surveillance activities were reviewed for the years 2008 and 2012. The results were then complemented with a critical scoping review of the literature aimed at identifying disease surveillance strategies and methods that are currently suggested as best suited to target vector-borne diseases in order to guide future development of surveillance in the countries in question.

Passive surveillance was found to be efficient for early detection of diseases during the early phase of introduction into a free country. However, its value diminished once the disease has been established in a territory. Detection of emerging diseases was found to be very context and area specific, and thus active surveillance designs need to take the available epidemiological, ecological and entomological information into account. This was demonstrated by the effectiveness of the bulk milk surveillance in detecting the first case in Sweden, highlighting the need for output based standards to allow the most effective, context dependent, surveillance strategies to be used. Preparedness was of fundamental importance in determining the timeliness of detection and control in each country and that this in turn was heavily influenced by knowledge of emerging diseases in neighboring countries. Therefore it is crucial to share information on outbreaks between researchers and decision-makers and across borders continuously in order to react timely in case of an outbreak. Furthermore, timely reaction to an outbreak was heavily influenced by availability of control measures (vaccines), which is also strengthened if knowledge is shared quickly between countries. The assessment of the bluetongue surveillance in the affected countries showed that the degree of voluntary engagement varied, and that it is important to engage the public by general awareness and dissemination of results. The degree of engagement will also aid in establishing a passive surveillance system.

Keywords

Animal health, surveillance, vector borne diseases, bluetongue

Introduction

Over the past ten years, emerging infections caused by vector-borne pathogens have increasingly become a challenge for Europe, with examples such as bluetongue virus (Faes et al., 2013), Schmallenberg virus (Afonso et al., 2014) as well as the zoonotic Crimean-Congo Haemorrhagic Fever virus (Oncü, 2013) and West Nile virus (Bellini et al., 2014). A review study of 335 events of emerging infectious diseases (EID) (Jones et al., 2008) showed that 22.8% of all diseases evaluated were vector-borne, this number reaching 28.8% when only events in the previous 10 years were included.

Preparedness against vector-borne threats which can emerge unexpectedly in a given space and time depends on the existence of a long-term, sustainable surveillance of vector-borne disease and their relevant vectors which provides tools for prevention, earlier detection and effective control (Braks et al., 2014). We aimed at reviewing the availability of such surveillance systems in five European countries, and summarize literature recommendations for improvement of vector-borne surveillance.

For the first objective, we report an inventory of surveillance systems for vector-borne animal diseases in five countries in Europe – Denmark (DK), France (FR), Sweden (SE), the Netherlands (NL) and the United Kingdom (UK), which are the countries where five veterinary institutes participating in the CoVetLab network (www.covetlab.org) are located. The inventory also covered a more in-depth evaluation of the countries' surveillance systems specifically aimed at bluetongue (BTV-8 virus, specifically). The aim was to get an overview of the components of all surveillance systems at two points in time, 2008 and 2012, corresponding to early and late stages of the bluetongue outbreak that affected Europe between 2006 and 2010.

The results from the inventory are then complemented with a critical scoping review of the literature aimed at identifying disease surveillance strategies and methods that are currently suggested as best suited to target vector-borne diseases in order to guide future development of surveillance in the countries in question.

Methods

1. Inventory of surveillance systems in the CoVetLab partner countries

A questionnaire (available in the Supplementary information, S1) was designed to collect information about all components of all surveillance systems and surveys that had been used in the five study countries (DK, FR, SE, NL and UK) to investigate the occurrence of vector borne diseases or –agents, or vectors for these diseases, between January 2008 and December 2012. The list of animal diseases to focus on (Table 1) was based on an adjusted list created in the EPIZONE project (http://www.epizone-eu.net/) by WorkPackage 7.4 (Risk of new, emerging and re-emerging vector-borne viruses entering and becoming established in the EU due to effect of climate change).

For uniform interpretation, a *surveillance system* was defined as "A method of surveillance that may involve one or more component activities that generates information on the health, disease or zoonotic status of animal populations". A *surveillance component* was defined as "a self-contained surveillance protocol used to investigate the occurrence of one or more hazards in a specified population (e.g. serological bulk milk surveillance or surveillance of hantavirus in rodents)". The data collection was carried out by surveillance professionals with deep insight into their respective countries surveillance activities, with support from additional expertise from within their organisations.

2. Description and qualitative assessment of bluetongue surveillance

Based on the results of the inventory of surveillance systems, bluetongue (BTV-8) was chosen as a case study to perform a more detailed inventory of the surveillance systems in place. The year 2008 was chosen as the first year during which all 5 involved countries were affected by the outbreak. The project started in 2013, and therefore 2012 was the latest year for which consolidated surveillance information could be acquired. Figure 1 summarizes the timeline of the bluetongue epidemic that affected Europe from 2006, for the countries involved in this study.

However note that this information is presented as available through the WAHID Animal Health Information System from the World Organization for Animal Health (OIE), which does not allow separation of the serotype BTV-8 (focus of this study) from other serotypes.

The performance of a surveillance system can only be assessed in light of the primary purpose it is aimed at fulfilling, in order to define whether the purpose is being met. For this exercise, the primary purpose of surveillance for BTV in all countries was considered to be “Detection of previously absent disease”. The evaluation question was defined as “Was the surveillance at the time points evaluated, in each country, likely to detect outbreaks sufficiently early to allow their control (to meet policy maker needs)”.

The RISKSUR project (http://www.fp7-risksur.eu) has recently made publicly available a report (Calba et al., 2014) in which all of the attributes that have been identified as relevant to the evaluation of animal health surveillance are listed (Annex 1 of the report). The attributes are grouped into those that evaluate the structure, function, effectiveness and value of the surveillance. Epidemiologists from the five CoVetLab partner countries participated in a workshop during which these attributes were reviewed in order to select those that would be useful to assess the evaluation question defined, and identify which could be assessed within the scope of this work. Furthermore, the evaluation of the attributes were divided into first line attributes – those most closely associated with the performance of surveillance systems, and second line attributes – which have an impact on the first line attributes. The attributes regarded as relevant by the experts are listed in Table 2.

Based on the data collected, a qualitative evaluation was performed, and the main conclusions are presented in the results section.

3. Scoping review

For this literature review, two sources were searched on 21st January 2013: CabAbstract and Scopus. A list of keywords was drafted and combined into a Boolean query to identify the topics of this review, namely: *animal disease surveillance*, and more specifically *vector-borne disease surveillance*. The use of wildcards (*) ensured that articles containing any variation of each of the search terms were identified. The final query syntax was: (surveillance OR monitor*) AND (animal* OR livestock OR veterinar* OR fish* OR wildlife OR ”food system*” OR herd* OR farm* OR cattle OR cow* OR bovine OR ruminant* OR pig* OR porcine OR swine OR sheep OR goat* OR poultry OR bird* OR avian OR horse OR equine OR cat* OR dog*) AND (disease* OR health OR infection* OR outbreak) AND (vector* OR Culicoides OR midge* OR mosquito* OR tick* OR sandfl*)

All terms were searched for in both Title and Abstract. The literature search was restricted to articles written in English and published between 1993-2013 in SCI journals (Science Citation Information, available at http://www.sci-thomsonreuters.org/). The search for the scoping review built on a comprehensive systematic review conducted within the above-mentioned RISKSUR project, which had a much broader scope, covering all surveillance objectives, hazards and species subjected to animal health surveillance.

Once the list of identified articles was outlined, all the titles and abstracts were screened by two researchers using the primary exclusion criteria described in Table 3. Full texts of articles that remained were then screened by three reviewers using the secondary exclusion criteria described in Table 3.

The selected articles were grouped based on the themes found in the review. Within each theme the articles were summarized based on relevant characteristics of the disease covered; the vectors discussed; the country or region covered by the study; the data source used, the data collection method employed, the described surveillance aim, and the epidemiological design/sampling method. Other relevant characteristics identified during the review, by theme, are presented. The summaries of all papers reviewed, as well as the main conclusions reached are presented.

Results

1. Inventory of surveillance systems in the CoVetLab partner countries

Surveillance components identified in the inventory were categorized into four items:

1) *General passive animal health surveillance*. For the animal diseases surveyed (Table 1), all countries reported passive animal disease surveillance.
2) *Syndromic surveillance*. The Centers for Disease Control (CDC, USA) defines syndromic surveillance as those approaches which make use of “health-related data that precede diagnosis and signal with sufficient probability of a case or an outbreak to warrant further public health response” (CDC, 2006). Sweden, The Netherlands and France reported the existence of syndromic surveillance systems that covered the possible occurrence of West Nile virus in their territories. France also reported ongoing work to implement syndromic surveillance system that could cover early signs of Schmallenberg virus introduction, and Rift Valley fever.
3) *Hazard specific animal health surveillance*. Hazard specific animal health surveillance consists of diagnostic testing of blood samples from animals: antibodies detection or detection of RNA/DNA of pathogen by PCR. Table 4 gives an overview of hazard specific animal health surveillance systems, against vector-borne diseases, that were

operational in the five participating countries anytime between January 2008 and December 2012.

4) *Vector surveillance*. Vector surveillance aims at a) catching vectors (ticks, Midges, mosquitos, sandflies) and subsequent diagnostic testing of vectors caught for DNA/RNA of vector-borne pathogen by PCR; b) early detection of introduction of exotic vectors (prevention of establishment of exotic vector). Table 5 gives an overview of vector surveillance systems that were operational in the five participating countries anytime between January 2008 and December 2012.

2. Description and qualitative assessment of bluetongue surveillance

A full description of the data collected in order to assess the surveillance using the selected attributes is provided in the Supplementary information (S2), and the information is summarized below for the main topics covered. It was not possible to collect detailed and quantitative information for all the performance attributes within the framework of this project, and the data were therefore mainly assessed qualitatively.

Surveillance programs in place

Vector surveillance: The primary area of introduction of the BTV-8 epidemic that spread in Europe between August 2006 and the beginning of 2010 was Belgium close to the border with the Netherlands and Germany. All countries established vector surveillance after the start of outbreaks in their respective countries. This surveillance was focused on determining the vector free period, as required in the European Union legislation (Council Directive 2000/75/EC), and on detecting the presence and distribution of competent vectors. SE, UK and Southern FR, where the introduction of the BTV-8 virus occurred late in the epidemic, had vector surveillance operational before the time when the BTV-8 epidemic was first detected in their territory.

Serological surveillance: The countries that had serological surveillance in place before the start of outbreaks in their country (DK, FR, SE and UK) mainly focused on early detection, with demonstration of freedom from disease as a complementary objective. At the end of the epidemic, all countries had implemented serological surveillance focused on proving freedom of disease (nationally or in parts of the country), and determining the spatial spread of the disease.

Only the UK tested imported livestock for BTV-8 before the establishment of infection in its own country. In all countries, outbreaks were detected for the first time by passive surveillance, except Sweden where it was detected by active (bulk milk) surveillance before any clinical signs were apparent.

Costs

Investigated costs for *vector surveillance* and *serological surveillance* are listed in Table 6. An attempt was made to assess the value before and after the outbreak, but this was not always possible. The earliest year for which cost information was available, in each country, is provided in the table, as well as information for the year 2012 when available. The figures for FR and SE indicate that the national cost of *vector surveillance* need not be affected by an outbreak of a specific vector-borne disease. For *serological surveillance*, in both DK and SE the costs were considerably higher before the outbreak (to detect disease early or demonstrate freedom of disease) than after the outbreak (to determine freedom of disease). The costs for early detection comprised 50% and 85% of the costs in these two countries, respectively. In FR the costs for serological surveillance were increased approximately 15% between the years compareddue to the inclusion of the serotype BTV-8 (the program was initially targeting BTV serotypes 2, 9 and 16 in the south).

Timeliness

In DK, SE, UK and NL, it was estimated that 1-2 months passed from introduction of BTV-8 to the time it was first detected by surveillance. No data were reported from FR for this attribute in the questionnaires administered. The time from detection to predetermined action (control) was heavily influenced by the availability of a vaccine and also by the need to have policies in place. In FR and NL, 22 months passed from detection to the start of vaccination in the summer of 2008, and in UK and DK, the lag time was 7 and 8 months, with vaccination starting in July and April 2008, respectively. In contrast, it only took SE 2 days between detection (on September 6th, 2008) and action due to the late incursion (in relation to the other countries) which meant that vaccines were available and policies were in place. In other words, the observed delay from detection to action was highly related to the availability of a vaccine which in turn was dependent on the time of incursion in each country. This highlights the fact that even though efforts are made to optimize surveillance timeliness, the influence on timely action is far more dependent on pre-defined action plans and availability tools for control, such as having vaccines in stock in case of an outbreak.

Coverage

The serological surveillance programs in DK, FR, NL and SE were constructed to consider the whole cattle population. DK also reported sheep as the target population. The proportion of the target population actually sampled were, in 2012: for DK: 0.11%, FR: 0.7%, NL: 0.13% and SE: 4-9%.

Historical data

Data on the occurrence of BTV prior to the BTV-8 outbreak was only available in FR. In UK, the vector surveillance started as early as 2006 - light/suction traps were reported to be placed in 15 sites across England from early 2006. Data obtained before, during and after the outbreaks are kept at the national institutes responsible for the surveillance, but in general data are found in various formats with poor metadata, and are therefore difficult to retrieve and/or combine.

Implementation of surveillance and vaccination

In DK and FR, acceptability and engagement from farmers and stakeholders with respect to the decided control measures was generally low. There were challenges in finding sentinel herds in FR and general difficulties in engaging people. In NL, SE and UK there was a high degree of acceptability and farmers were generally positive towards voluntary vaccination, at least initially.

In DK and NL it was fairly easy to set up surveillance at short notice, due to a well-oiled veterinary administration. New personnel were hired in both countries to administer the vector surveillance. In SE and UK, the system to carry out surveillance targeted at the vector (non hazard specific) was built upon an already existing network for surveillance, and was therefore easily set up. In France, 3 different sampling strategies existed and made the implementation of the surveillance difficult.

Analysis and communication

In UK, NL and FR, various analyses have been conducted and the data have been used in several research projects. In all countries, information about the outbreak has been disseminated to the public, and papers in scientific journals about the outbreaks have been published. Furthermore, leaflets and web campaigns have been used to increase awareness about vaccination and other control measures.

The following institutes and organizations were involved in the central management and organization of the activities aimed at controlling the outbreaks: In Denmark, National Veterinary Institute (DTU VET) and the Danish Food and Veterinary Administration (DK); in France, the French agricultural research and international cooperation organization (CIRAD) and the French Agency for Food, Environmental and Occupational Health & Safety (ANSES); the Central Veterinary Institute (CVI), the Netherlands Food and Consumer Product Safety Authority and GD Animal Health in The Netherlands; the National Veterinary Institute (SVA) and the Board of Agriculture (SJV) in Sweden; and in the UK the Department for Environment, Food & Rural Affairs (DEFRA), Animal and Plant Health Agency (APHA) and the Institute for Animal Health (IAH).

3. Scoping review

The first query for animal disease surveillance papers published in the last 20 years returned 6295 results. After application of the primary exclusion criteria, 764 papers were selected for full-text download. Application of the secondary exclusion criteria resulted in 328 papers relevant for the animal disease surveillance theme. From those, 43 were selected as relevant to the specific theme of vector-borne threats. One key paper addressing innovative methods for surveillance against vector-borne diseases, published after the date of the review (Madouasse et al., 2013), was included.

Figure 2 shows the year of publication of the articles included in this review. Most papers reported on studies conducted in Europe (n=21). Seven papers discussed general methodologies, not focusing on any specific countries. The other remaining 16 were distributed as follows: Africa (3); Asia (1); Australia (1); North America (9); South America (2).

Table 7 shows the host species of interest in the studies reviewed. The total is greater than the number of papers (44) because some studies included more than one species. Those listed as "several" considered hosts more broadly (without focusing on any particular species) or focused only on the vector, not on the hosts. Table 8 shows the vectors considered. Eighteen papers did not focus on a particular vector. The threats considered by the papers are detailed in Table 9. Ten papers did not discuss one particular threat, but focused on vector surveillance in general, or discussed several possible vector-borne threats. Bluetongue (a non-zoonotic agent) and West Nile Virus (a zoonosis) were the most commonly discussed threats.

The 44 papers reviewed were classified into five groups based on their main focus. Those groups and further subgroups are listed in Table 10. In the supplementary material (S3) we provide full summaries of all 44 papers reviewed, for each of these groups. The key themes from the review are listed below.

The first key theme is the high relevance of ***passive surveillance***, most particularly in areas free from a disease. This is corroborated by a quantitative evaluation carried out by Souza-Monteiro *et al* (2012), in which the authors used information-gap theory to show that if an efficient passive surveillance is in place, then active surveillance may be wasteful allocation of resources. That applies to diseases not present in an area, and assumes good reporting capacity by farmers (which depends on awareness and willingness to report among farmers and veterinarians, good laboratory capacity, etc.). The papers reviewed also demonstrated that passive surveillance alone is not effective once the disease has been introduced.

Another dominant theme in the review was the use of ***risk-based surveillance approaches***, with risk being defined geographically based on the (potential) distribution of the vectors. Due to this need to evaluate geographical risk, the use of risk-mapping was very common. However, several short-comings of risk-mapping were identified, and the occurrence of an emerging disease in the past did not always match the expected areas of new introduction. One study showed that current environmental data is not as good for estimating the risk of disease as taking into account data from a whole season. As a result risk-maps worked well retrospectively, but their use in forecasting/prospective monitoring must bear in mind the potential limitations.

Not surprisingly, ***entomological surveillance*** was an important component of the majority of surveillance systems designed to monitor or control vector-borne diseases. This involved active vector trapping – with or without testing for the agent – and analysis of environmental data in parallel with vector density data. However it was continuously highlighted that this type of surveillance needs to be carried out for long periods, in order to generate a useful baseline.

Lastly, ***sentinel surveillance*** was also a common theme when discussing early detection of vector-borne disease introduction. It was highlighted that mammals are better sentinels than birds when the goal is early detection of diseases that threaten humans. Livestock are commonly used, or dogs and horses in case of zoonotic diseases. Some studies also described the use of wild boar (young ones). The use of sentinel animals resulted in case detection before entomological surveillance showed results, so the use of sentinel surveillance is recommended for early warning surveillance (even when entomological surveillance is in place). However, there is no single formula for how sentinel surveillance should be implemented, and the design should be specific to the country and context in which it is placed. Particular attention should be paid to the distribution of risk factors within the country, such as climatic and geographic factors that affect vector presence. The methods listed to investigate those risks and their distributions are listed in the supplementary material (S3), and included cluster detection methods, and more often regression models to investigate the effect of various risk factors. Similarly, the season during which to conduct surveillance should take into consideration the ecology of the vector. The review also pointed out that decisions need to be based on a better integration of epidemiological, ecological and entomological data.

In public health, the European Centre for Disease prevention and Control has published Guidelines for the surveillance of invasive mosquitoes in Europe (ECDC, 2012). These guidelines are intended to harmonise procedures in Europe and support their implementation. Animal health stakeholders interested in vector-borne surveillance are encouraged to consult this reference.

Discussion

Using the experience of five countries during an outbreak of bluetongue, complemented with a scoping review of surveillance against vector borne diseases, we aim to summarize the lessons learned so far, which could guide the design of surveillance systems targeting animal populations with the aim of preventing or controlling vector borne diseases.

The first lesson learned from this work is the identification of effective surveillance strategies for early detection of vector borne disease. All five countries had passive surveillance in place for Bluetongue and other vector borne disease prior to the occurrence of the outbreak. Indeed, passive surveillance was the mode of detection of the bluetongue virus introduction in four of the five countries, the exception being Sweden. This is in line with the results of the literature review which highlighted the importance of passive surveillance for early-detection, and highlights the importance of national awareness and dissemination of information to to farmers and veterinarians.

One of the papers reviewed suggested that if efficient passive surveillance is in place then active surveillance may be a wasteful allocation of resources (Souza-Monteiro et al, 2012). The potential benefit of well-designed active surveillance for early detection was demonstrated by the detection of disease using bulk-milk surveillance in Sweden before passive surveillance had detected the outbreak. This reflects the late introduction in Sweden when compared to the other countries, enabling establishment of additional surveillance components aiming at earlier detection of introduction.

Bulk milk surveillance was not recommended in the legislation at the time, but the context specific information led surveillance designers to implement the bulk milk survey which proved to be sensitive and cost-effective. The main driver of the decision to actively screen the cattle population was the fact that clinical signs are not expected to be very evident in bovine (Sternberg Lewerin et al., 2010). The success of this choice highlights the need to set legislation focused on the desired goals of surveillance (output-based surveillance), which in this case was a high sensitivity for detection of an introduction, rather than restricting the methodology to be used (input-based) (Cameron, 2012; More et al., 2009).

As learned from the literature review, and from the BTV-8 case in Sweden, early detection of emerging diseases in general, and of vector-borne diseases in particular, is highly context specific, and surveillance designers should be able to take into consideration the epidemiological, ecological and entomological information available for a specific area, at a specific period of time, when deciding the most appropriate method to achieve surveillance goals. The literature review highlighted that context information needs to be included in both host surveillance and entomological surveillance. The use of risk-maps was particularly common, but the need for better integration of epidemiological, ecological and entomological data was emphasized.

The review also highlighted the importance of sentinel surveillance for early detection of vector borne disease, again emphasizing the need for this to be tailored for the particular context of each area and time period. It is interesting that none of the countries included in this study had implemented sentinel surveillance. In contrast several countries were in the process of setting up syndromic surveillance systems. As yet there is no evidence to support the use of these systems for early detection of vector borne disease but these methods have only recently been introduced in animal health so time will reveal how effective they are, highlighting the need for continuous assessment of the effectiveness of different surveillance approaches.

The second main lesson was the identification of effective surveillance once an outbreak had occurred. Although passive surveillance was identified as highly relevant for early detection it was not thought to be sufficient as an effective case detection tool for disease control once the disease has been introduced. The data collected in this study revealed that the general pattern seen was that when an introduction of a vector-borne disease was detected by (in majority) passive surveillance, free (neighbouring) countries started active surveillance for early detection (in vectors and in animals). During the vector-borne disease outbreaks in a country, active surveillance was carried out to investigate competent vectors, estimate disease prevalence/incidence and to prove freedom of disease at the end of the epidemic.

Ad-hoc surveys are the most widely used active surveillance strategies used for vector-borne disease surveillance. The only continuous surveillance programs that exist in the participating countries are passive surveillance. Ad-hoc surveys consists of early detection of vector-borne-disease in vectors and animals after detection of the vector-borne disease in neighbouring countries; or b) active surveillance after detecting a vector-borne disease in the country, testing blood samples or testing trapped vectors.

The third and final main lesson from this work is the importance of preparedness for the detection and control of vector borne disease. Generally, the results indicate that it is important to have a high degree of national awareness in order to detect an outbreak. Vectors know no borders. Timely detection of an outbreak in one country will be of benefit to its neighbors who will get more time to prepare for a possible outbreak in their own country. Furthermore, focus on the situation in neighboring countries is important. This was clearly illustrated by the late introduction in Sweden when compared to the other countries, enabling establishment of additional surveillance components aiming at earlier detection of introduction. The need for a coordinated approach on the prevention and control of vector-borne diseases has also been highlighted after the Schmallenberg virus outbreak in Europe in 2011 (Roberts et al., 2014).

The importance of the link between surveillance and control actions was highlighted in this work, in particular the impact of the availability of control strategies, in this case a vaccine, on the timeliness (time from detection to action). In general, the timeliness of control measures will depend on to what extent action plans and control strategies are in place, and to what extent they efficiently can accommodate the scenarios that are evolving.

The results of the surveillance systems inventory and evaluation must be seen in light of the outbreak timeline, considering that The Netherlands and France had to deal with the introduction very early in the overall European outbreak, while the other three countries could already have learned from their experience by the time introduction was detected. Moreover the level of disease awareness was much higher in the other countries at the time they faced disease introduction, in comparison to The Netherlands and France. This was reflected in the high timeliness (from detection to action) observed in Sweden. This shows the value of immediately sharing outbreak information internationally so that neighboring countries can prepare actions in case of an increased threat of an outbreak.

Several factors that can contribute to preparedness were identified in this work including the availability of historical data. The scoping review performed incorporated 44 peer reviewed articles. The small number of papers selected (in comparison to the 764 papers that were selected for full-text download) reflects the choice of inclusion criteria, which restricted the review to papers with adequate descriptions of the surveillance activities in place. Such detailed descriptions of implemented surveillance systems may often not be published in scientific, research-based peer reviewed journals, or may be available only in the country's native language.

Another factor that can influence preparedness is the availability of existing surveillance activities. If there has been no ongoing vector surveillance in a country before an outbreak, for instance, time will be spent on setting up a surveillance program and training personnel. Lastly, the general opinion of the farmers and stakeholders towards governmental actions is important. A negative opinion will create barriers to implementation of both serological and vector surveillance programs.

Conclusion

This investigation of the surveillance carried out in 5 countries (DK, FR, NL, SE and UK) during the BTV-8 outbreak in Europe showed that the detection of emerging diseases is very context and area specific. Although passive surveillance was efficient for early detection of diseases in most countries, the role of active surveillance in Sweden showed that surveillance designs need to take the available epidemiological, ecological and entomological information into account.

Another important result was that the preparedness was of fundamental importance in determining the timeliness of detection and control in each country and that this in turn was heavily influenced by knowledge of emerging diseases in neighboring countries. Furthermore, timely reaction to an outbreak was heavily influenced by availability of control measures (vaccines), which is also strengthened if knowledge is shared quickly between countries. The assessment of the bluetongue surveillance in the affected countries showed that the degree of voluntary engagement varied, and that it is important to engage the public by general awareness and dissemination of results.

Acknowledgments

The authors would like to thank the CoVetLab (www.covetlab.org) for funding this work. We would also like to thank Erika Chenais (SVA), Adam Brouwer (APHA), the Danish Food and Veterinary Administration, Rene Bødker (DTU VET), Anette Bøtner (DTU VET), Bertel Strandbygaard (DTU VET).

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Figure captions

Figure 1. Status of Bluetongue (not restricted to BTV-8) in the domestic animal population of each of the five countries participating in the study, as reported to the World Organisation for Animal Health (OIE). Data retrieved through the World Animal Health Information Database (WAHID) Interface (OIE, 2014). Clinical disease definitions used as provided by the system (available at: http://www.oie.int/wahis_2/public/wahid.php)

	2005		2006		2007		2008		2009	
	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec	Jan-Jun	Jul-Dec
Denmark	Never reported	Never reported	Never reported	Never reported	Never reported	Disease presence	Disease not reported during this period	Disease presence	Disease presence	Disease not reported during this period
France	Disease limited to one or more zones	Disease not reported during this period	Disease not reported during this period	Disease limited to one or more zones	Disease not reported during this period	Disease limited to one or more zones	Disease presence	Disease presence	Disease presence	Disease presence
The Nether-lands	Never reported	Never reported	Never reported	Disease presence	Confirmed infection but no clinical disease	Confirmed infection but no clinical disease	Disease suspected but not confirmed	Disease presence	Disease presence	Disease not reported during this period
Sweden	Never reported	Never reported	Never reported	Never reported	Never reported	Never reported	Never reported	Confirmed infection but no clinical disease	Disease limited to one or more zones	Disease not reported during this period
United Kingdom	Never reported	Never reported	Never reported	Never reported	Never reported	Disease limited to one or more zones	Disease limited to one or more zones	Disease not reported during this period	Disease not reported during this period	Disease not reported during this period

Figure 2. Number of publications included in the literature review, by year (total = 44).

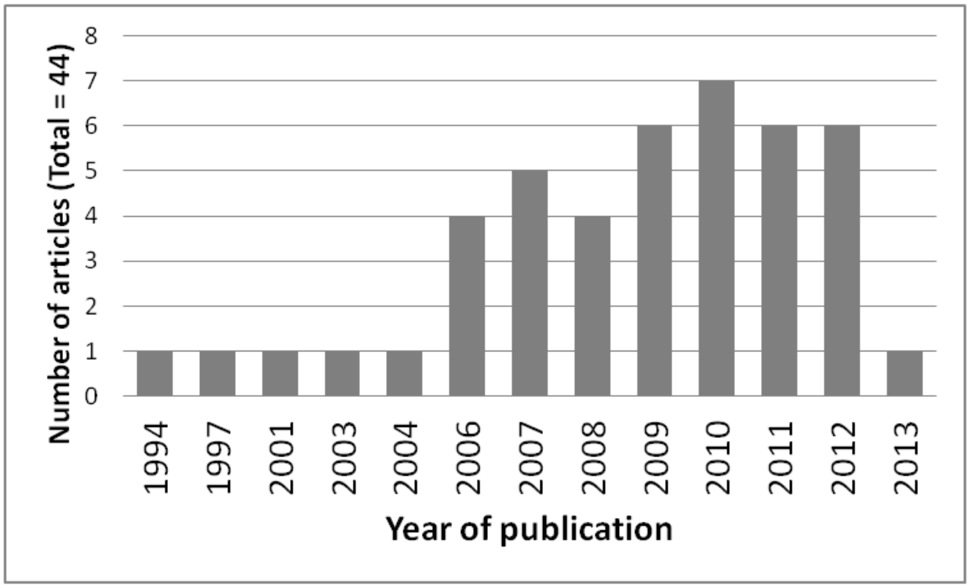

Table 1. List of diseases included in the inventory of surveillance systems against vector borne diseases in the CoVetLab partner countries (DK, FR, NL, SE, UK).

Pathogen (or disease)	Vector			
	Culicoides biting midges	Mosquitoes	Ticks	Sandflies
Bluetongue virus	√			
African horse sickness virus	√			
Equine encephalosis virus	√			
Epizootic haemorrhagic disease virus	√			
Schmallenberg virus	√			
Akabane virus	√			
Bovine ephemeral fever virus	Vector unclear			
West Nile virus		√		
Tularaemia		√		
Usutu		√		
Japanese encephalitis virus		√		
Rift Valley fever virus		√		√
African swine fever virus			√	
Louping ill			√	
Lyme disease			√	
Tick Borne Encephalitis virus complex			√	
Crimean-Congo Haemorrhagic Fever			√	
Alkhurma haemorrhagic fever virus			√	

Table 2. Attributes chosen for the evaluation of the performance of existing surveillance systems for bluetongue disease in the CoVetLab partner countries (DK, FR, NL, SE, UK).

Group	Attribute	First line	Second line	To be assessed in this work
Assessment of value	Economic acceptability	X		Not possible to quantify in the project
	Benefit	X		Not possible to quantify in the project
	Cost	X		Yes – If data available
Related to effectiveness	Timeliness	X		Yes – discussed using data from retrospective samples for known diseases
	Sensitivity		X	Yes – theoretical according to the design of surveillance
	False alarm rate		X	Yes – Use number of negative reports for known diseases
	Coverage of high risk population		X	Yes - Use number of reports for passive surveillance and coverage estimates for active
Function	Acceptability and engagement		X	Yes – discussed using incentives and barriers e.g. compensation and awareness campaigns
	Historical data		X	Yes - what did we know about vector presence before incursion
	Simplicity		X	Yes
Processes	Data collection		X	Yes - how does data collection carried out compare with ideal data collection for vector-borne disease
	Communication and dissemination		X	Yes
	Data storage and processing		X	Yes
	Data analysis		X	Yes
Support	Organisation and management		X	Yes
	Training provision		X	Yes
	Resource availability		X	Yes

Table 3. Primary and secondary exclusion criteria used in the article selection process for the scoping review of surveillance methods applied to vector-borne diseases.

Primary exclusion criteria	The paper is not related to surveillance programs;
	The paper reports results of surveillance without description of surveillance methods;
	The paper presents case reports/outbreak investigations;
	The paper presents experimental infections;
	The paper presents the results of field surveys not based on a systematic data collection, or a single study of prevalence estimation;
	The paper is focused on surveillance of human diseases exclusively;
	The paper is focused on the evaluations of diagnostic tests/methods;
	The paper is focused on intervention measures rather than on surveillance (for instance assessment of the impact of vaccination strategy);
	The paper describes a pilot or an evaluation of a surveillance system but without fully describing surveillance methods;
	The paper is focused on the evaluations of vaccine efficacy;
	The paper is focused on the molecular characterizations of pathogens;
	The paper is a review of an animal disease;
	The paper is a pure theoretical study, or focuses on statistical methods or tools development without clear link o surveillance application;
	The paper presents a risk analysis.
Secondary exclusion criteria	Unavailability of full-text version;
	The paper provides insufficient information to allow the evaluation of described methods;
	The paper does not describe any surveillance design/methods;
	The paper presents a primary exclusion criterion that was not apparent from reading the titles and abstracts only.

Table 4. Hazard specific animal health surveillance systems, against vector-borne diseases, that were operational in the five participating countries anytime between January 2008 and December 2012.

Disease	Denmark	France	Sweden	The Netherlands	United Kingdom
Bluetongue	X	X	X	X	X
Schmallenberg		X	X	X	X
West Nile	X				X
African Swine Fever	X		X		
Usutu virus	X				

Table 5. Vector surveillance systems that were operational in the five participating countries anytime during the period between January 2008 and December 2012.

Disease	Denmark	France	Sweden	The Netherlands	United Kingdom
Bluetongue	X	X	X	X	X
Schmallenberg	X	X	X	X	X
West Nile				X	
Usutu virus				X	
Afr Horse Sickness		X			
Lyme Disease		X		X	
Tick-borne Encephalitis		X		X	
Detect exotic vector				X (mosquitos)	

Table 6. The yearly costs for *vector surveillance* and *serological surveillance*. The earliest year of the outbreak for which information was available is reported, as well as the information available for the year 2012 in each of the five investigated countries, as reported in the inventory carried out.

Country	Early time point			Late time point		
	Year	**Vector surveillance**	**Serological surveillance**	Year	**Vector surveillance**	**Serological surveillance**
DK	2007	Not carried out	10,000 €	2012	130,000 €	5,000 €
FR	2009	400,000 €	3,400,000 €	2012	400,000 €	3,900,000 €
NL		Not carried out before the outbreak		2012	520,000 € yearly during the outbreak, already stopped in 2012	Not available
SE	2008	110,000 €	78,000 €	2012	110,000 €	13,000 €
UK	No cost information provided on the questionnaire					

Table 7. Host species evaluated in the 44 papers reviewed for the scoping review of surveillance methods applied to vector-borne diseases (some papers considered more than one species group).

Host species	**Number of articles**
Birds	4
Dogs	3
Ducks	1
Horses	5
Humans	6
Mice	1
Rats	1
Ruminants	12
Wild animals	1
Several	17

Table 8. Vectors evaluated in the 44 papers reviewed for the scoping review of surveillance methods applied to vector-borne diseases.

Vectors considered	Number of articles
Ectoparasites (general)	1
Fleas	1
Midges	8
Mosquitoes	10
Phlebotomine sandfly	1
Ticks	5
No particular vector	18
TOTAL	44

Table 9. Diseases discussed in the 44 papers reviewed for the scoping review of surveillance methods applied to vector-borne diseases.

Threat	Zoonotic	Number of articles
Bluetongue	No	12
CCHF and ASF	Yes, No	1
EEE, HJ, JC, KEY viruses	Yes	1
Hearthwater infection	No	1
Leishmaniases	Yes	2
Lyme disease	Yes	2
Plague (Yersinia pestis)	Yes	1
Rift Valley Fever	Yes	3
Scrub typhus	Yes	1
SNV	Yes	1
WEE and SLE	Yes	1
West Nile Virus	Yes	8
No particular threat or various	--	10
TOTAL		44

Table 10. Groups and subgroups into which the 44 papers reviewed for the scoping review of surveillance methods applied to vector-borne diseases were assembled for discussion.

Paper focus	**Subgroups**	**Number of papers**
Discuss specific methods	Risk mapping	3
	Climate change	1
	Surveillance design	1
	Syndromic surveillance	2
Vector surveillance	Vector prevalence study	4
	Vector presence study	2
	Vector introduction assessment	1
Host surveillance	Sentinel investigation	3
	Host prevalence study	3
	Reservoir prevalence study	3
Surveillance system description	Data validation	1
	Description	11
	Evaluation	4
Review papers		5
	TOTAL	44